1995-1996

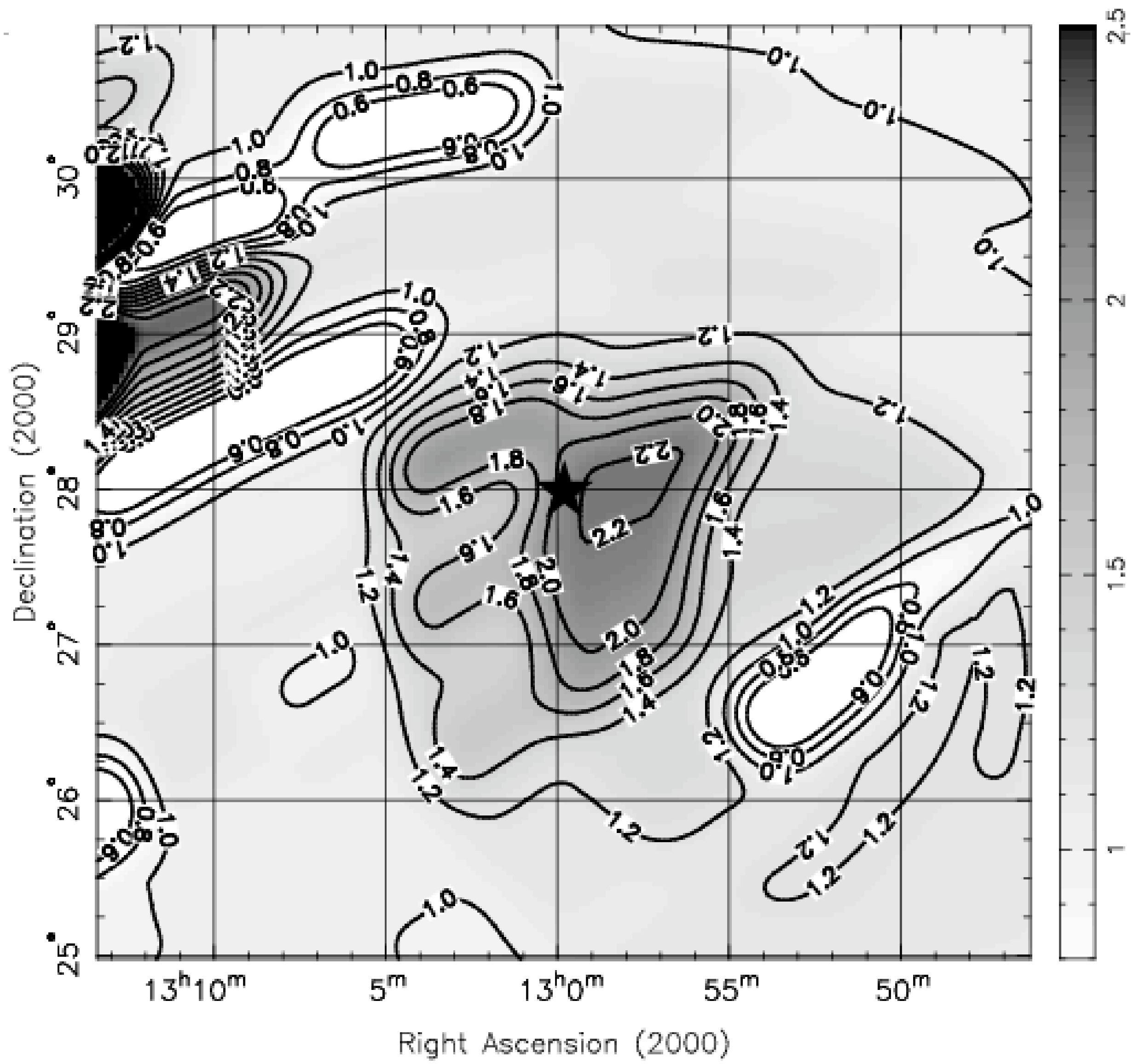
The EUV and soft X-ray excess in Virgo and Coma clusters were interpreted as due to a warm ($T < 10^6$ K) component of the cluster IGM (Lieu et al., 1996, ApJLett + Science)

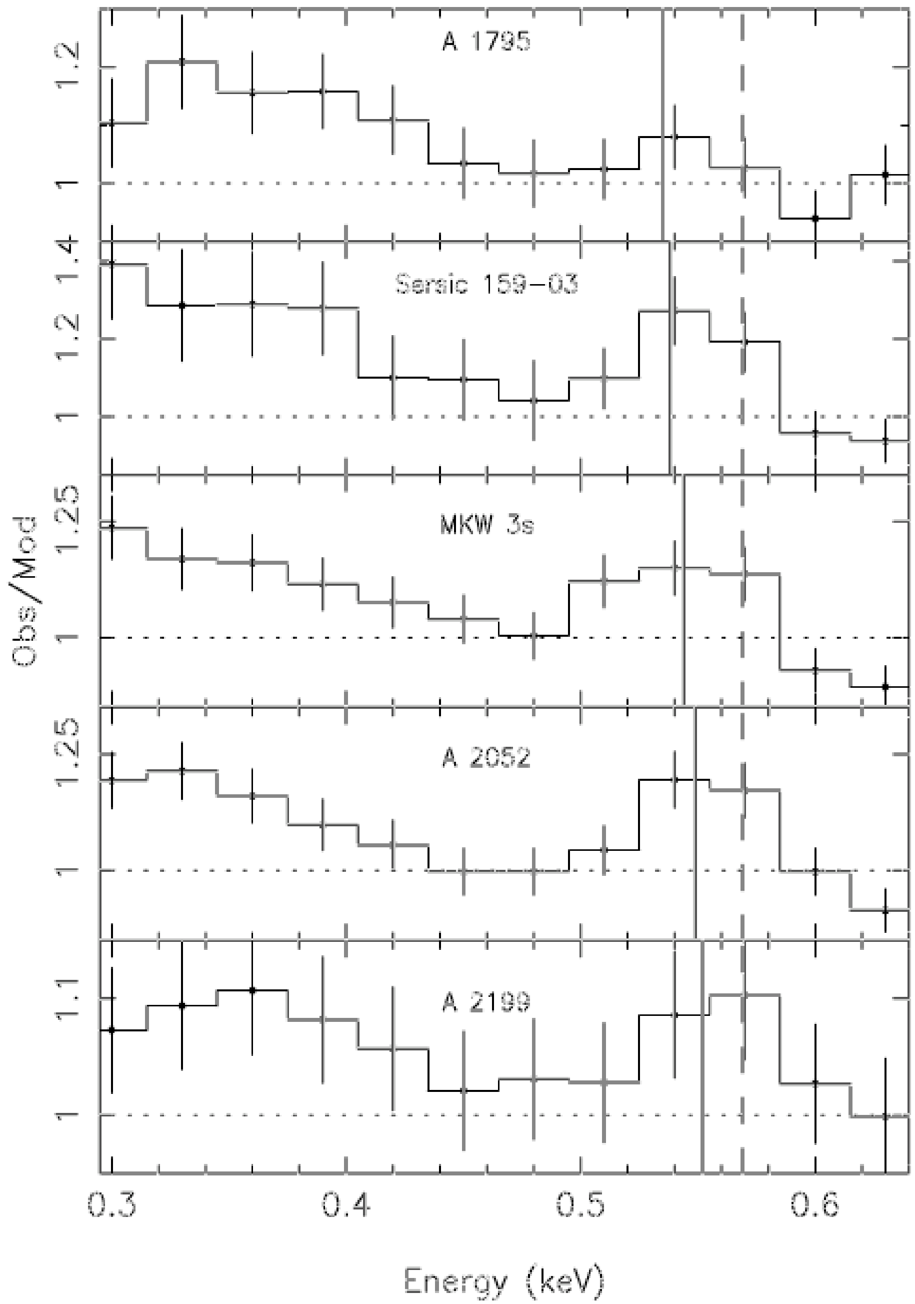
2001-present

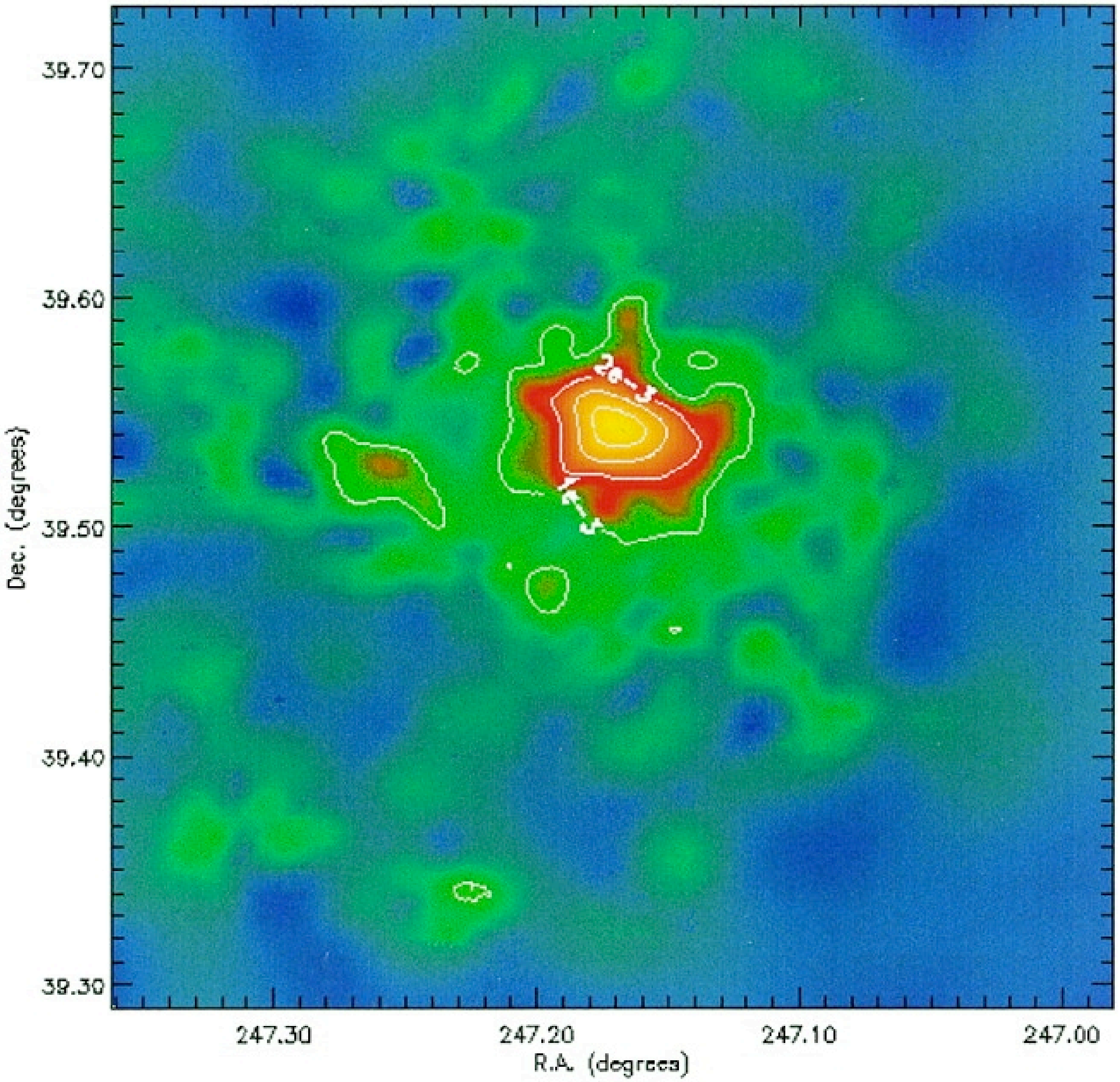
Today confirmations are provided by the XMM-Newton mission which has detected OVII and OVIII emission in the soft excess spectrum of many clusters (but see also ROSAT evidence)

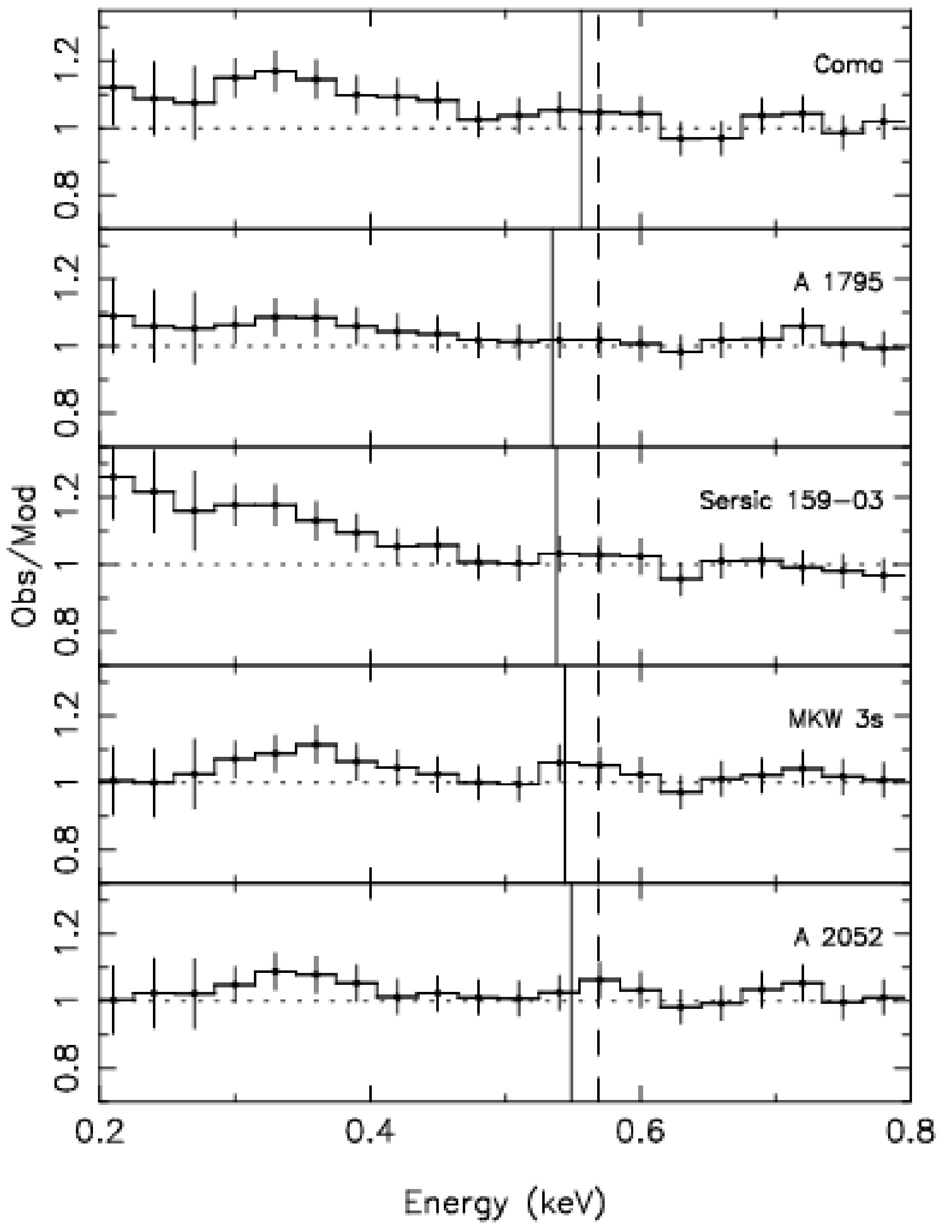
DO THE OBSERVATIONS AGREE WITH THEORY?

The soft excess emission may be too bright…


Declination (2000)
Right Ascension (2000)
13h10m
5m
13h0m
55m
50m
25°
26°
27°
28°
29°
30°
2.5
2
1.5
1


A 1795
Sersic 159-03
MKW 3s
A 2052
A 2199
Obs/Mod
Energy (keV)
0.3
0.4
0.5
0.6
1.2
1
1.4
1.25
1.1


39.70
39.60
39.50
39.40
39.30
Dec. (degrees)
247.30
247.20
247.10
247.00
R.A. (degrees)
2e-3
1e-3

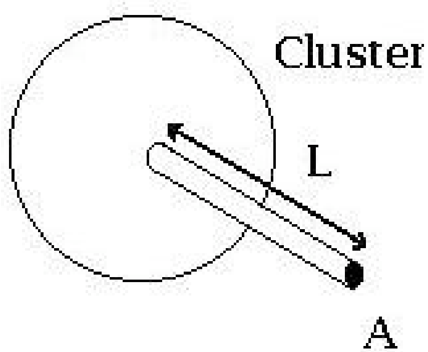


Coma
A 1795
Sersic 159-03
MKW 3s
A 2052
Obs/Mod
0.8
1
1.2
0.2
0.4
0.6
0.8
Energy (keV)

If emission is caused by warm *intercluster* filaments

Can avoid the need to make pressure balance with the hot intracluster gas. n_w can then be $< 10^{-2}$ cm^{-3}

BEWARE: of constraints due to this scenario. The emission Measure EM



$$EM = n^2 L A$$

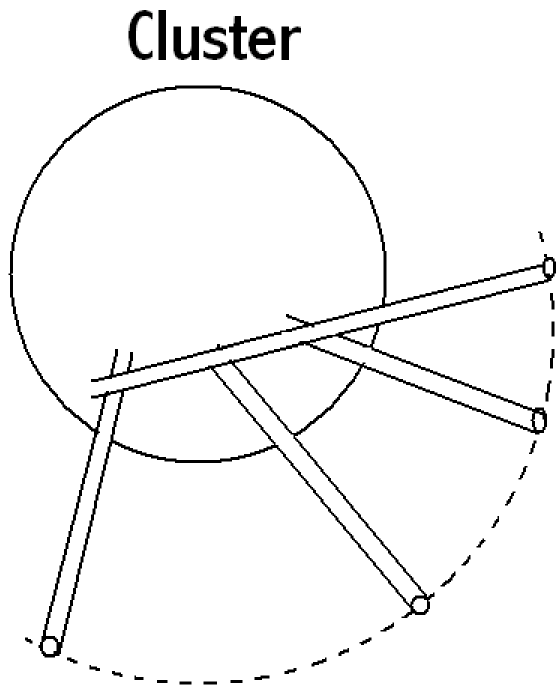
Is fixed by observations. For the Coma cluster the 0-20 arcmin Central radius this is 10^{68} cm^{-3} (Bonamente et al. 2002) giving

$L = 3\,(n/10^{-3}\text{ cm}^{-3})^{-2}$ Mpc ..hence.. $N_H = 10^{22}\,(n/10^{-3}\text{ cm}^{-3})^{-1}$ cm^{-2}

Give significant line opacities but not continuum opacities

Mass budget of WHIM

Assume filaments form `spaghetti' converging onto a node (cluster)

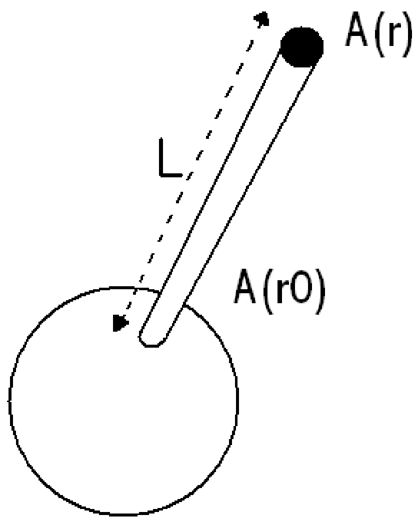


Total mass of warm gas is:

$$M = 4/3\ \pi\ L^3\ n\ m_p\ f$$

Where f is a volume filling factor that decreases with increasing L

If filaments converge to entire cluster surface at $r = r_0$



$$f(r) = f(r+L) = \frac{A(r)\ r_0^2}{A_0\ r^2}$$

For constant Xsectional area and $L >> r_0$ we have

$$f = (r_0/L)^2$$

Then for Coma

$$M_{WHIM} = 10^{14}\ (n/10^{-3}\ cm^{-3})^{-1}(r_0/0.5\ Mpc)^2\ M_{sun}$$

SOFT EXCESS & THE COOLING FLOW RIDDLE

Can we do away with the non-thermal interpretation of the soft excess?

Within the inner radii the soft excess is very bright – it even outshines the cooling flow. Here the thermal model is untenable inside and outside the cluster

However, if the inflowing gas is adiabatically compressed by a factor α , the gas pressure $P_{gas} \sim \alpha$ but the pressure of any embedded relativistic particles $\sim \alpha^{(\mu+2)/2}$ where μ is the differential power-law no. index

Ratio $$\frac{P_{CR}}{P_{gas}} \sim \alpha^{(\mu-1)/3}$$

ConX simulation of Coma 11 model. 10^4 seconds: